DOCUMENT RESUME

ED 206 047 EA 013 765

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TITLE Ability and Learning: A Theoretical and Empirical Synthesis.
INSTITUTION Illinois Univ., Chicago. Chicago Circle Campus.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE [80]
GRANT NIE-678-0090
NOTE 41p.: This document is Part K of a compilation entitled "Generalized Theory of Design and Analysis of Educational-Effectiveness Research." For related documents, see EA 013 759-761, EA 013 763-767, ED 168 714, ED 185 064, and EJ 210 984.

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Academic Ability; Academic Achievement; *Cognitive Ability; Elementary Secondary Education; Group Testing; *Intelligence; Intelligence Tests; *Learning; Models; *Outcomes of Education

ABSTRACT

To gauge the relationship between intellectual ability and learning, the authors review the work of 20 theorists and analyze empirical correlations at both the elementary and secondary school levels. Intellectual ability is defined in the paper as including intelligence, prior learning, special aptitudes, and other cognitive characteristics. The authors discuss six paradigms of intellectual ability developed by the theorists, involving operational measures (IQ tests), learning rates, stimulus-response associations, cognitive development stages, components of ability, and information processing. Next, to estimate the magnitude of the relationship between ability and learning, the authors analyze 396 correlations derived from the literature. Intellectual ability was measured in the correlations by group intelligence tests relating to verbal, nonverbal, quantitative, or "total" ability. The results indicate that overall academic achievement correlates most highly with verbal ability, followed by total ability, nonverbal ability, and quantitative ability. Correlations were consistently lower between group intelligence tests and class grades than between the intelligence tests and standardized achievement tests. (Author/RW)

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Ability and Learning: A Theoretical and Empirical Synthesis

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EA 013 765

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Abstract

The contribution of 20 intelligence theorists are reviewed and organized according to six conceptual paradigms. In addition empirical evidence is reported concerning the magnitude of the ability-learning relationship found with commonly used group intelligence tests. A total of 396 correlations are summarized. Results indicate that correlations between verbal intelligence and achievement are highest ($\bar{x}$=.721), followed by total ability ($\bar{x}$=.699), nonverbal intelligence ($\bar{x}$=.638) and quantitative ability ($\bar{x}$=.599). Correlations were consistently lower between group intelligence tests and grades ($\bar{x}$=.572) than between group intelligence tests and achievement tests ($\bar{x}$=.702). Implications of the conceptions of ability and learning for educational productivity are drawn.

Ability and Learning: A Theoretical and Empirical Synthesis

Few educators would dispute the importance of individual students' ability in accounting for school learning. The existence of stable individual differences in ability and their importance to education was recognized as early as the turn of the century when Binet and Simon (1905) published an intelligence scale to identify subnormal children attending the Paris schools. Since that time, many theorists have addressed the problems of describing and explaining differences in cognitive abilities, especially intelligence.

In this paper, the contributions of 20 theorists are briefly reviewed. Their work has been organized around six distinct paradigms, distinguished by their intents, methodologies, and disciplinary roots. Following this review, a second major section of the paper is devoted to empirical evidence concerning the magnitude of ability-learning relationships found with commonly used group intelligence tests. Implications are drawn for the inclusion of ability as one of the nine factors in Walberg's (1980) psychological model of educational productivity. It should be understood that even though ability may not be manipulable in the same way as some of the other factors in the model, its inclusion has definite implications for educational practice, and it is indispensable in any comprehensive, explanatory model of schooling outcomes.

In the model of educational productivity the ability factor includes not only intelligence, but also prior learning, special aptitudes and other cognitive characteristics which the learner brings to the classroom. The in-depth treatment in this paper of ability as intelligence should not be taken to imply that other conceptions of ability, such as Bloom's (1976) cognitive entry behaviors, are not of significant importance to the model. The topic of ability as intelligence was selected for this paper to illustrate the types of analysis and to highlight the issues relevant to this important productivity factor.

Conceptions of Intelligence: A Historical and Theoretical Review

Defining the concept of intelligence has captured the attention of many educators, psychologists, and philosophers. As early as the fifteenth century, commentators have spoken of "intelligentia" as a unitary thing which guided the actions of all humans (Spearman, 1927).

Herbert Spencer formulated an early definition of intelligence which relied upon Darwin's theory of evolution. Spencer, a biologist, defined life as the continual adjustment of internal relations to external conditions. Intelligence, for Spencer, achieves the adjustment in humans, in contrast to instincts in animals. After Spencer's introduction, the concept of intelligence quickly became popular among psychologists, and they developed many intelligence and aptitude tests. In France, Binet and Simon constructed tests to identify mentally deficient children in the Paris schools. In Germany, mental tests were developed in order to conduct experimental studies in psychopathology and various educational problems. Galton, in Great Britain, was developing mental tests to study the relationship between heredity and individual differences. Little interest existed, however, in studying the nature of intelligence itself.

With the development of so many mental tests, psychologists tried but failed to reach agreement on a definition of intelligence. Many symposia were conducted but consensual agreement on a definition was never obtained. Spearman (1927) summed up the situation in his assertion that the term "intelligence" with so many diverse meanings, in reality had no meaning at all. A consideration of a few of the diverse definitions of intelligence which were developed will serve to support Spearman's position.

Overview

The six paradigms referred to in organizing this review are listed in

Table 1, together with associated theorists. First discussed is the development of the most widely used individual intelligence tests by Binet and Simon (1916), Terman (1916), and Wechsler (1974). These tests were designed to meet practical needs for diagnostic tools, but came to serve as operational definitions of intelligence.

Following the discussion of these instruments, two paradigms are reviewed in which theorists attempted to explain differences in intelligence by reference to physiological or neurological variations. Woodrow (1946) conceived of intelligence as a reflection of learning rate, and sought evidence of a unitary learning rate that could be used to characterize individuals. In the third paradigm considered, Thorndike (1927) and Thomson (1939) developed models based upon simple stimulus-response associations, and related intelligence to differences in number of neural connections that could be modified.

The last three paradigms represent current areas of active research. The first of the two developmental theorists is Hebb (1949), who distinguished intelligence as an innate capacity, from intelligence as a degree of neurological elaboration acquired through experience. The second developmental psychologist is Piaget (Inhelder & Piaget, 1964), whose stage theory of cognitive development has profoundly influenced educational practice.

The fifth and largest category of theorists includes those who have used factor analysis to identify distinct components of intellectual ability. This paradigm has led to the identification of numerous distinct types of ability--over 100 in one widely recognized theory (Guilford, 1967).

The last of the six approaches reviewed subsumes the information processing models of Newell and Simon (1972) and Miller, Galanter and Pribaum (1960), as well as Sternberg's (1977) componential analysis and recent contributions by Jensen (1979a, 1979b) employing somewhat similar techniques. The work of some

major theorists within each of these traditions is briefly discussed in the following sections.

Empirically-Based Operationalizations for Diagnostic Purposes: Paradigm 1

One of the earliest and perhaps most influential members of the psychological community concerned with a practical definition of intelligence was Alfred Binet. His definition of intelligence was never published in a final form (Peterson, 1925), but he did have a point of view which has influenced the development of numerous mental tests. Binet did not emphasize sensory and motor functions as did Galton and other British psychologists. Although Binet placed some emphasis upon memory and imagery, he heavily emphasized judgement, common sense, and problem solving--all abilities which he believed to involve direction, comprehension, invention, and criticism. These numerous abilities recognized by Binet caused him to regard intelligence as very complex. He viewed mental abilities as being independent and unequal, and expected that, for example, an individual with little memory might be very capable of making judgements. Each of the various subtests he and Simon developed was constructed to measure only one intellectual ability (Peterson, 1925). Ironically, Binet chose to represent intellectual complexity using a single number, the mental age. This decision was in contradiction to his belief that intelligence was made up of many abilities. Guilford (1967, chap. 1) speculates that the reason for calculating a single score was to facilitate making a single administrative decision on each child tested.

In America, Lewis M. Terman became the champion of Binet's test. In 1916, he released the standardized Stanford-Binet Scale. Over the years the test was revised several times with the most significant change being the introduction of the IQ score or intelligence quotient index: 100 (mental age/

chronological age) (Terman and Merrill, 1937). The Stanford-Binet test dominated individual testing for many years. Weschler (1974), however, had some reservations about the use of different tests for each age on the Stanford-Binet. He preferred to measure the same abilities at all ages. In addition, he believed, based on empirical data, that there may be several abilities affecting performance on intelligence tests, and several scores (rather than a single IQ quotient) may better reflect this reality. Given these two concerns, he constructed the Weschler Intelligence Scale for Children (WISC), and the Weschler Adult Intelligence Scale (WAIS). Both of these tests and the more recent version for preschoolers were scored to yield both a verbal and performance IQ, and even more differentiated scoring schemes have been developed.

In summary, the work of Binet, Terman and Weschler resulted in the construction of individual intelligence tests that were developed for diagnostic purposes. Item and subtest development in these instruments was based more on the empirical performance of children of different ages rather than specific theories of intelligence.

Ability as Learning Rate: Paradigm 2

Another major conception of intelligence equated learning ability with intelligence. This conception of intelligence relied upon the assumption that learning ability is a universal fact regardless of the substance of what is learned. It went beyond the mere measurement or description of differences by means of mental tests, to the investigation of a physiologically based, potential causal mechanism. Empirical support for this conception was never strong. Woodrow (1946) conducted a series of studies that suggested that learning and intelligence are separate factors. Two basic findings emerged from his work. First, he intercorrelated a large battery of simple learning tasks with each other as well as with IQ. A factor analysis of the intercorrelations failed to

reveal a general factor of learning ability. Second, in his studies, learning ability was operationalized as rate of improvement between the pre- and posttest of simple learning tasks. He found little or no correlation among learning rates from various learning tasks or between learning rate and IQ. Overall, his results seemed to indicate that speed of learning simple tasks and rate of improvement with practice are not related to IQ.

Ability as Determined by Stimulus-Response Associations: Paradigm 3

E. L. Thorndike (1927) and Godfrey Thomson (1948) also posited simple physiological mechanisms to account for ability differences. Thorndike viewed intellectual potential as the number of neural connections in the brain which could be modified. He hypothesized that simple stimulus-response associations could account for complex cognitive behaviors, and the number of these associations could account for differences in the complexity of tasks different persons could solve.

The British psychologist, Thomson (1948) proposed a sampling model of "g," or general intelligence. Using results from a factor analysis and drawing upon a model similar to Thorndike's, he explained the general and group factors in terms of differential sampling of neural connections in the tests. In Thomson's view, neural elements are sampled by the more complex tests, hence, higher intercorrelations are found among them.

The test construction activities of Binet, Terman and Weschler, experimental psychologist's examinations of the relationship of learning rate and intelligence, and theories based on neural connections, all represented attempsts to define intelligence. However, the systematic study of the nature of intelligence to determine the structure as well as its function became the province of primarily three approaches: developmental or genetic, factor analytic, and information processing--all of which are active areas of current research.

Developmental Approaches: Paradigm 4

Hebb's (1949) work represents an early developmental approach to the study of intelligence. On the basis of clinical evidence, he postulated two components of intelligence. The first is a heredity or physiological component whose deficit is evidenced by the impairment of learning ability in brain-damaged infants and children. The second component depends on experience and permanent changes in the organization of neural pathways in the brain. Hebb believed that the hereditary factor is responsible for elaborating perceptions and conceptual activity; the experiential factor is the degree to which the elaboration had occurred (e.g., concepts of number, of causal relations, common human behavior). Hebb labelled these two components simply: Intelligence A and Intelligence B. Intelligence A amounts to the possession of a good brain and a good neural metabolism, while Intelligence B is reflected in the experienced-developed functioning of a brain, and it determines the average level of performance or comprehension by an individual. Neither type of intelligence can be directly observed, but B can be more directly inferred from behavior than A.

Hebb's theory is developmental in that it is based on clinical data and postulates an interaction between a stimulating environment and innate potential. As interactions occur the neural pathways of the brain are modified, and more elaborate conceptual growth occurs.

Jean Piaget offers a currently more influential theory, that is also based upon clinical observation and postulates an interaction between environment and innate potential. Piaget and his colleagues provide characterizations of the successive stages of intellectual development. In Piaget's view, intelligence, which is the extension of certain fundamental biological characteristics, can be divided into three aspects: content, function, and

structure (Inhelder & Piaget, 1964; see also Flavell, 1963, for an introductory overview). Content encompasses the observable behavior of the individual which the psychologist attempts to interpret. Function refers to the principles of intellectual activity common to all ages. Encompassed within the broad category of function are two principle processes, assimilation and accommodation, that maintain the organism's cognitive equilibrium. Assimilation is the process of taking in information present in the environment. The information becomes part of the individual's structure of knowledge through accommodation, which is the process of changing the individual's schemata in the light of the information being assimilated. Both of these processes are continuous in individuals of all ages. Structure, the third aspect of intelligence, refers to concepts which develop and change with age and experience. Some of the concepts which have been investigated by Piaget include: classes, relations, quantity, number and conservation of quantity and space. As children develop, their use of these concepts becomes more logical in a formal sense (Inhelder & Piaget, 1964). The sequence of development which leads to the use of formal logic is hierarchical; each stage builds on a previous stage, and all of them occur in an invariant order (Inhelder & Piaget, 1964).

This developmental sequence has several stages within it. Of particular interest are the stages of concrete operations and formal operations. The concrete stage, typical of children under eight, involves thought bound by events and objects of the real world and little abstraction. Adolescents and adults achieve a stage of formal operations in which thought is no longer bound by externals and has become more internalized and logical.

Piaget's clinical observations provide a description of stages of intellectual development through which all individuals are said to pass. Piaget also constructed tasks which indicate an individual's stage of intellectual and assess the availability and use of the schema mentioned earlier.

Piaget seems less interested in individual differences in intelligence as such than in determining and characterizing the stages of intellectual

development through which all individuals may pass. Nonetheless, his work has found application in the description and diagnosis of special learning difficulties, and the Piagetians have drawn implications for curriculum development.

Factor Analytic Approaches to the Study of Intelligence: Paradigm 5

Another approach to the study of intelligence is represented by those theorists who use multivariate methodology as their primary tool. A long series of contributions have been produced by these theorists. In this section, the work of each of the following multivariate theorists will be briefly considered: C. Spearman (1927), L. L. Thurstone (1935), C. Burt (1949), P. E. Vernon (1950), R. B. Cattell (1963), J. P. Guilford (1967), H. E. Garrett (1946), and A. R. Jensen (1969).

Spearman (1927) was the first psychologist to use factor analysis in an attempt to explain the structure of intelligence. His work led to the conclusion that intelligence is composed of a general factor "G" and a large number of specific factors which he referred to as "s" factors. In his two-factor theory, intelligence is represented primarily by the "G" factor which is common to all mental abilities. Everyone possesses the "G" factor in varying amounts and Spearman (1927) believed it to be the most important aspect of intelligence measured by intelligence tests. "G," or general intelligence, is held to account for the substantial intercorrelations among many intelligence tests, according to Spearman, because these tests measure this same ability. The most important characteristic of "G" is that it requires insight into relationships.

When Spearman was confronted with evidence of uncorrelated intelligence tests, his explanation made use of "s," or specific, factors which were held to be unique to each type of mental ability. An example of a specific or "s"

factor was rote memory. In general the "s" factors did not involve insight into relationships.

For Spearman, all mental activities had a common "G" factor which was the most important characteristic. In addition, each mental activity had its own specific ability or abilities. As Spearman continued his work, he recognized that a group of mental tests share some variance in addition to that accounted for by "G." He considered this additional variance to be due to what he called a "group factor." Since Spearman did not view group factors as significant, he did not actively investigate them. Intelligence tests, according to Spearman (1927), should be constructed to measure the "G" factor, and "s" factors should be minimized, thereby leaving "G" as the crucial measure of intelligence.

Spearman's two-factor theory was discounted by Thurstone (1938) who used a different factor analytic procedure, the centroid method of factor extractions, to examine the structure of intelligence. He noted that often when tests are factor analyzed there is neither a universal "G" factor, nor a large number of "s" factors, rather there are several group factors. "Group factor theory," which was Thurstone's contribution to the study of intelligence, is based upon the intercorrelations among limited numbers of tests. He believed it to be the best theoretical base for studying and discussing intelligence (Thurstone, 1938).

Thurstone's original work included the administration of 56 tests of mental abilities to a large number of adults. Through factor analytic procedures he accounted for performance on the 56 tests with seven factors. These seven factors represent mental abilities which Thurstone claimed were the primary components of any complex intellectual performance. Because the seven abilities correlated weakly or moderately, Thurstone argued that no

general intellectual factor existed. In time, Thurstone's position changed in that he found evidence to support a "second-order factor" which unites the primary group factors.

British followers of Spearman held to his original notion of a "G" factor, but as evidence supporting the existence of group factors grew, several of Spearman's followers developed hierarchical models to explain the interrelationships among specific, group and general factors (Guilford, 1967, chap. 3). Burt (1949) conceived of a hierarchy of mental abilities representing all of the human mind. There is a factor corresponding to each mental ability differentiated at each level of the hierarchy. The entity of the human mind contains two general factors, "G" and "practical abilities." Successive dichotomizations occur as the model moves from general factors to group factors, and finally to specific factors. As the model is presented, it departs from strict dichotomizations since there are points at which a higher level ability contains more than two abilities at the next lower level of generality.

Vernon's (1950) model, also hierarchical in nature, postulates "G" and other major group factors. In turn, each group factor contains minor group factors, and beyond these factors are very specific factors each having a narrow scope and considered by Vernon to be trivial (Guilford, 1967, chap. 3). For Vernon, "G" is dichotomized into "v:ed" or verbal educational and "k:m" or practical abilities. The "v:ed" factor contains two minor factors: "verbal" and "numerical." The "k:m" factor contains three abilities: "spatial ability," "manual ability" and "mechanical information." Beyond these are the very specific factors.

The concept of "G," as developed by Spearman (1927), has been criticized by several theorists including Thurstone (1938) and Guilford (1967) who have

pointed out that its characteristics, rather than being invariant, are entirely dependent on the test battery used. "G" is not invariant. One of the theorists who moved away from the notion of "G" was R. B. Cattell.

Cattell (1963) developed a theory of intelligence which has two factors: "fluid" and "crystallized." The fluid factor represents an innate ability which requires abstract reasoning, but little specific information. Tasks requiring fluid ability necessitate the reorganization of knowledge (Cronbach, 1970, chap. 9). The crystallized factor represents acquired information. Obviously, fluid intelligence remains relatively constant (but possibly declines in old age). Crystallized abilities, on the other hand, increase with age.

For Cattell (1963), the notion of fluid ability is intimately associated with culture-fair intelligence tests. Tasks requiring crystallized ability, on the other hand, use information and skills which are the direct result of instruction and are culture bound.

Guilford (1967), after conducting extensive research, became disenchanted with the hierarchical models which had evolved from earlier theories of intelligence. Research had revealed the existence of many different intellectual factors, and conflicting evidence surrounded "G." Guilford (1967) concluded that even the hierarchical models could not adequately reflect the structure of intellect, and he turned to a morphological model. This model is a cross classification of intellectual phenomena with intersecting categories rather than nested categories. Guilford's model employs three independent dimensions: content, operation, and product. Any mental ability represents one category in each dimension, resulting in a total of 120 possible intellectual abilities. An intellectual factor results when any one of the five types of operation combines with any one of the six types of product and any one of

four types of content. The content, operation, and product dimensions are briefly described below.

The content dimension is an extension of the distinction between verbal and nonverbal abilities. The four content categories classify the type of input which is processed. The operation dimension provides five categories of types of processing to be applied to the various types of content. The classification of factors according to product describes the form of the information which is to be processed. Which one of the six product categories is used is determined by the granularity and types of interrelationships existing in the input.

Garrett (1946) employed a combination of the developmental and factor-analytic approaches. He performed factor analyses on scores from a battery of various intellectual tasks administered to children of different ages. Garrett's factor analyses yielded different factors for the various age levels. He concluded that as children mature, mental abilities become more differentiated.

Jensen (1969), in developing his model of intelligence, drew heavily upon the work of factor analysts with regard to his definition of Level II intelligence, or conceptual ability, which can be viewed as somewhat analogous to Spearman's "G." In developing the argument to support Level I intelligence, or rote memory, Jensen relied upon the tradition of experimental psychology which historically has examined learning ability as a unitary factor regardless of content. Jensen contends that the two types of abilities, Level I and Level II intelligence, are hierarchically dependent, with Level II processes necessitating the memory abilities which are part of Level I. The notion of hierarchical dependence between abilities was contributed by Burt (1949) and Vernon (1950). White (1965), an American learning theorist using the

experimental method, also influenced Jensen with his theory of hierarchical arrangement of learning processes. In the light of this eclectic approach, Jensen has contributed a unique theory of intelligence which combines the factor analytic approach with experimental learning theory.

Jensen's (1969) theory posits two types of intelligence. Level I intelligence, originally referred to by Jensen as "basic learning ability," is the capacity to receive or register stimuli, store them, and later recall or recognize material accurately. Level I is characterized by absence of any elaboration, transformation, or manipulation of the input in order to arrive at the output (Jensen, 1979). The learner need not refer to past learning. Forward digit span is one of the clearest measures of Level I intelligence, whereas reverse digit span is not as pure a measure since transformation of input is required prior to output. Serial rote learning and paired associate learning are also examples of Level I ability. Level I intelligence (Jensen, 1969) is the source of most individual differences on tasks requiring little transformation of input.

Level II intelligence is characterized by transformation and manipulation of the stimulus prior to making the resonse (Jensen, 1980). Jensen stated that Level II intelligence is the set of mechanisms which make generalization beyond primary stimulus generalization possible, as well as concept formation, encoding and decoding of stimuli in terms of past experience, relating new learning to old learning and transfer of concepts and principles (Jensen, 1969).

Information-Processing Theories of Intelligence: Paradigm 6

During the last two decades there have been attempts to produce information-processing theories of intelligence. Sternberg (1977) has pointed out that these theories are not of the scope of the factor analytic theories.

The latter cover a broad range of cognition, whereas the information-processing models emphasize in-depth examinations of more narrowly circumscribed performance. Information-processing approaches generally require a detailed task analysis and posit some specific sequence of cognitive operations required to accomplish the task analyzed. Compared to factor-analytic approaches, they are more concerned with the analysis of mental processing of a given individual than with the description of differences in mental ability among individuals. While process is addressed by some factor analytic theorists (Guilford, 1967), task content, rather than process, has been the predominant organizing principle in multivariate research. Factor analytic and information processing approaches may ultimately be synthesized to arrive at a fuller understanding of the dimensions and mechanisms of cognition. Information-processing models in their present stage of development, however, are quite distinct from any of the other paradigms reviewed.

Newell and Simon (1972) defined the fundamental units of mental ability as "elementary information processes," or eip's. These fundamental units were not to be taken as irreducible, but rather as representing the decision of the investigator as to the level of analysis at which to begin. Different researchers might begin with different eip's, depending upon the behaviors to be understood. Once eip's are defined, they are organized into condition-action sequences known as productions, and these in turn are organized into ordered sequences known as production systems. An "executive" scanning the productions in the production system, initiates them in sequence when appropriate conditions are met.

Miller, Galanter and Pribrum (1960) proposed a somewhat different fundamental behavioral unit known as the TOTE-unit, an acronym for Test, Operate, Test, Exit. These units were combined in flowchart-like sequences to model

complex behavior patterns, called PLANs, that are similar to those modeled by Newell and Simon.

Sternberg (1977, 1979) presented another model with four levels of organization. His fundamental units are called components, and are organized into subtasks which in turn comprise composite tasks. The activation of components is via meta-components, which correspond in some ways to the "executive" of Newell and Simon's system. Sternberg has investigated his model by the use of what he has termed componential analysis. Using carefully designed tasks which are hypothesized to differ systematically in their information processing requirements, he has arrived at estimates of the time required for certain fundamental processes by subtracting the times individuals require to complete tasks with different requirements.

A similar method, also involving measurements of the times required for certain simple tasks, has recently been employed by Jensen (1979a) to explore the nature of intelligence and its relation to learning. Using simple and choice reaction times as well as movement times, Jensen (1979b) has been identifying clues which may lead to explanations of individual differences in mental abilities in terms of the kinds of processes that information theorists have identified.

Summary

The various theorists have provided a rich variety of concepts and perspectives on human cognitive abilities. Some have been concerned with the practical problems of measuring individuals' abilities, with little concern as to their origins or fundamental nature, while others have derived complex models of cognitive processes and their interrelationships, seeking to understand the performance of single individuals on single tasls. Some have studied the course by which abilities change and increase as children mature,

while others have considered only the performance of adults. Another such distinction of special importance to education is set forth in Table 2. This is the classification of conceptions of ability as process versus acquired content. Inspection of Table 2 shows that not every theorist conforms to one or the other of these conceptions. For example, Cattell's fluid intelligence is clearly defined in terms of process, while his crystallized intelligence represents content acquired. Thus, Cattell appears in both columns of the table, and the same is true of other theorists, as well.

Neither conception precludes the alterability of intelligence through appropriate educational experiences. However, the two conceptions differ in their implications for curriculum and instructional methods. A conception of intelligence in process terms would imply that educational productivity might best be enhanced through the teaching of strategies and learning heuristics. On the other hand, if intelligence is conceived as acquired content, educational productivity might best be enhanced by simply imparting more information to students. Fortunately, the educator is not forced to choose between these extreme positions. Just as a number of intelligence theorists have incorporated both perspectives, so most curricula incorporate both instructional approaches. What is important is to recognize that strong theoretical support exists for both process and content definitions of ability.

Empirical Investigation

The relationship between student ability and scholastic achievement is undisputed, and there would be little purpose in amassing empirical evidence merely to document that such a relationship exists. However, in the context of a model of educational productivity (Walberg, 1980), it was desirable to estimate the magnitude of this relationship, so that its potency could be

compared to that of other productivity factors. It was also necessary to ascertain whether the magnitude of the ability-achievement relationship varied systematically as a function of grade level or types of operationalizations of ability and achievement.

To this end, the literature was searched for correlations between ability and achievement measures. These correlation coefficients themselves were used as data points in the statistical summaries reported below. Thus, means of coefficients and standard deviations of coefficients are reported. The sources used were technical manuals for widely used, published group intelligence tests or, where these were not available, correlations cited in reviews of these instruments. A total of 396 correlations were located, including 333 correlations between group ability tests and academic achievement tests, and 63 correlations between group ability tests and course grades or grade point averages. The remainder of this section describes the literature search, statistical tabulations and conclusions.

Literature Search

When new tests of intellectual abilities are validated, their correlations with achievement in school are generally investigated. Large, representative samples are drawn, and test administration conditions are carefully controlled. Thus, technical manuals for these instruments provided an excellent source for such correlations. In conducting the search it was first necessary to decide what types of tests should be used to operationalize ability. It was decided to limit the search to published group ability tests in order to obtain estimates directly comparable to those for other productivity factors in the educational productivity model. Most of these factors have been operationalized using group-administered paper-pencil measures, hence the use of similar measures for ability was desirable. In addition, the content of such paper-pencil

measures generally resembles that of instructional materials used in the schools.

In order to select the specific tests to be included, a list of the most popular group ability tests was consulted (Cronbach, 1970, pp. 276-80). Of the 15 tests on this list, six were eliminated because they were primarily employment or personnel classification tests, were not published in English, or were designed to predict achievement beyond the twelfth grade level. Eight of the nine remaining tests were included in the data collection. For the remaining test no correlations with academic achievement were reported in manuals. To supplement the list provided by Cronbach with more recent instruments, the Seventh Edition of Buros Mental Measurement Yearbook (1972) was consulted. All reviews of group intelligence tests appearing in that edition were inspected in an attempt to locate additional correlations between such measures and achievement test scores. This search yielded correlations with only one additional ability measure. In all cases data were collected on the most recent test editions possible. Table 3 presents a list of the instruments for which validity coefficients (correlations between IQ tests and achievement tests and/or grade point average) were recorded. In collecting these correlations between ability and achievement, we noticed that the correlations of prior achievement with subsequent achievement were slightly higher than the ability-achievement correlations.

Classification of Ability Tests and Achievement Measures

Correlations involving several types of ability tests or subtests were included in the synthesis. The largest category was tests of verbal abilities, but non-verbal ability tests were also represented. Correlations involving verbal and non-verbal ability measures were tabulated separately. Some of the

ability tests included "quantitative" subscales, focusing primarily upon numerical or mathematical content. Support for a distinct quantitative ability is afforded by Thurstone's Primary Mental Abilities model as well as the Guilford Structure of Intellect model. Given the importance of mathematical content in the school curriculum, correlations involving these quantitative ability measures were also placed in their own category. In addition to specifically verbal, non-verbal and quantitative ability measures, a category was created for correlations involving relatively undifferentiated "total ability" measures. While these tended to resemble the verbal tests, they generally included various item types, not all of which were completely language-bound.

In addition to categorizing ability-achievement correlations according to the type of ability represented, correlations were categorized according to the type of achievement data employed. Initially, twelve different achievement categories were distinguished, including achievement tests in nine subject areas, overall grade point average, and grades in each of two specific school subjects. In order to reduce the number of achievement categories, the means of validity coefficients involving each type of ability and each category of achievement were inspected. As would be expected, small interactions were found between ability types and achievement types. Quantitative ability measures correlated slightly higher with mathematics achievement test scores than reading and vocabulary scores (means of .671 vs. .585; $t(15) = 1.48$, N.S.). On the other hand, verbal ability measures correlated more highly with reading and vocabulary test scores than with mathematics scores (means of .788 vs. .672; $t(92) = 7.80$, $p < .01$). This small interaction was deemed unimportant, however, relative to the substantially larger differences between correlations involving achievement test scores as opposed to course grades or grade point

averages. For this reason, the data were collapsed across achievement content areas after preliminary inspection, and only the distinction between test scores and grades was maintained. Three grade ranges were distinguished: grades 1-4, 5-8, and 9-12. Summary statistics for each combination of the four ability types, two achievement types and three grade ranges are presented in Table 4. In addition, stem and leaf diagrams and five point summaries are presented in Figures 1 through 4 for each ability-type by achievement-type combination.

Results

The summary in Table 4 shows a slight tendency for correlations to be higher in the middle grade range. This effect is not large, and may be due to the lower reliability of tests used with younger children and the restricted range of ability in the older, high school samples.

The results also indicate that correlations involving verbal ability are highest ($\bar{x}$=.721), followed by total ability ($\bar{x}$=.699), nonverbal ability ($\bar{x}$=.638), and quantitative ability ($\bar{x}$=.599). This pattern probably reflects the verbal saturation of most academic achievement tests and instructional tasks. The lower correlations for quantitative ability tests may be due to the relative specificity of this type of ability.

Another strong effect evident from Table 4 concerns the two types of achievement measures; correlations with test scores are markedly higher ($\bar{x}$=.702) than correlations with grades ($\bar{x}$=.572). This effect is due in part to the greater reliability of test scores relative to grades. However, it also reflects the fact that many factors other than test performance influence grades, and raises the important question of whether, for purposes of the educational productivity model, achievement should be conceived in terms of test scores or more broadly, in terms of all the factors that enter into teachers' deliberations when grades are assigned.

Turning from Table 4 to the stem-and-leaf diagrams in Figures 1 through 4, the difference in the magnitude of ability-test and ability-grade correlations is readily apparent. The stem and leaf diagrams combine features of a histogram and a frequency distribution (Tukey, 1977). The value of each correlation is represented, to two decimal places, by a "stem" (first decimal place) and a single "leaf" (second decimal place). The "stems" are the numbers to the left of the vertical bars, and the "leaves" appear to the right. In Figure 1, for example, in the left half of the figure, the leaves "444" appearing to the right of the stem ".5" represent three correlations: .54, .54, and .54. The next line up shows a stem of .5 and the leaves 58, representing correlations of .55 and .58. The overall shape of the stem and leaf display gives the same information as a histogram. Inspection of the stem-and-leaf diagrams for correlations with achievement test scores versus grades clearly shows that the grade correlations tend to be lower. In each of the four figures, the distribution of ability-grade correlations, in the right-hand half of the figure, appears to be shifted downward relative to the distribution of ability-test correlations in the left-hand half of the figure. The distributions tend to show a slight negative skew, and no serious outliers are apparent. These observations are confirmed by the 5-point summaries accompanying each diagram. The 5-point summary provides, for each distribution, the minimum (*), first quartile (H), median (M), third quartile (H), and maximum (*) of the data presented.

Conclusions

Taken together, the results of the empirical investigation support the inclusion of ability as a factor in the educational-productivity model. Group-administered tests of verbal ability correlate from .40 to .90 with achievement tests in a range of school subjects across grade levels 1 to 12,

with the median correlation being .74 and the mean correlation (from Table 4) being .71 for grades 1-4, .75 for grades 5-8, and .76 for grades 9-12. When achievement is operationalized by grades rather than test scores, correlations with verbal ability range from .37 to .75 with a median of .53, and means of .63 for grades 5-8 and .50 for grades 9-12. An important question raised by this analysis is the appropriate operationalization of achievement in the productivity model: Higher correlations are obtained with test scores than with grades, but the latter may represent a broader range of significant schooling outcomes than do test scores alone. The differences in ability correlations with these two types of outcome measures remind us that test scores are not the sole determinants of success in school or in later life.

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Table 1

Classification Scheme of Selected Operationalizations of Ability Based on Research Paradigm Employed

PARADIGM	THEORIST AND CONCEPTUAL DEFINITION
1. Empirically-Based Operationalizations for Diagnostic Purposes	Binet (1916) mental age
	Terman (1916) IQ
	Weschler (1974) deviation IQ, separate Verbal and Performance scores
2. Ability as Learning Rate	Woodrow (1946) Learning rate is not a unitary phenomenon
3. Models Based on Number of Stimulus-Response Associations	Thorndike (1927) connections
	Thomson (1939) sampling theory
4. Developmental	Hebb (1949) intelligence A is genetic, intelligence B is a product of genetic ability and nurturance
	Piaget (Inhelder & Piaget, 1964), schemata
5. Factor Analytic Models	Burt (1949) Hierarchical Model: 4 levels: sensations, perceptions, associations and relations
	Cattell (1963) Fluid and crystallized intelligence
	Garrett (1946) Differentiation of ability with age

Table 1 (cont.)

	Guilford (1967) structure of intellect model
	Jensen (1969) Level I and Level II intelligence
	Spearman (1927) "G"
	Thurstone (1938) primary mental abilities
	Vernon (1950) Hierarchical Model: verbal: educational vs. spatial: perceptual: practica
6. Information Processing Models	Jensen (1979a, 1979b) Reaction time experiments
	Miller, Galanter and Pribram (1960) PLANS
	Newell and Simon (1972) Elementary information processes analogous to list-processers, compilers, etc.
	Sternberg (1977) Components

Table 2

Classification Scheme of Operationalizations of Ability

as Process or Content Acquired

Process	Content Acquired
Binet (1916) and Terman and Merrill (1937) Subtests Reproductive design from memory Repeats digit string backward	Binet (1916) and Terman and Merrill (1937) Subtests "Define orange, envelope" "Compares laziness and idleness"
Burt (1949) Sensation and perceptual levels; memory; productive associations; and higher relational level	Burt (1949) Word factor; language factor; arithmetic ability; practical ability
Cattell (1963) Fluid intelligence	Cattell (1963) Crystallized intelligence
Garrett (1946) Increasing differentiation of ability with age	Guilford (1967) Contents dimension
Guilford (1967) Processes dimension	Hebb (1939) Intelligence B
Hebb (1949) Intelligence A	Thomson (1939) Sampling theory
Jensen (1969) Level I and II intelligence	Thorndike (1927) Connections
Jensen (1979a, 1979b) Response time experiments	Thurstone (1938) Number or spatial ability
Miller, Galanter & Pribram (1960) PLANS	Vernon (1950) Verbal and number factor; mechanical information
Newvell and Simon (1972) Elementary information processess	Wechsler (1974) Subtests "Similarities" "Information" "Arithmetic" "Vocabulary"
Piaget (Inhelder & Piaget, 1964) Schemata	
Spearman (1927) "G"	
Sternburg (1977, 1979) Components	
Thurstone (1938) Fluency and speed factors	
Vernon (1950) Induction; spatial ability; fluency and creative abilities	
Wechsler (1974) Deviation IQ; separate verbal and performance scores Subtests Digit span Block design	
Woodrow (1946) Learning rate	

Table 3

List of Group Ability Tests Used in the Research Synthesis

American College Testing Program (anon.,[1] American College Testing Program)

California Test of Mental Maturity (E. T. Sullivan. W. W. Clark, E. W. Tiegs; California Test Bureau)

Cooperative School and College Ability Tests (anon., Educational Testing Service)

Henmon-Nelson Tests of Mental Ability (M. J. Nelson, et al., Houghton Mifflin Co.)

Kuhlmann-Anderson Measure of Academic Potential (F. Kuhlmann and R. G. Anderson, Personnel Press)

Lorge-Thorndike Intelligence Tests (I. Lorge, R. L. Thorndike, Elizabeth Hagen, Harcourt, Brace & World)

Otis-Lenon Mental Ability Test (A. S. Otis and R. T. Lennon, Harcourt, Brace & World)

Scholastic Aptitude Test (anon., College Entrance Examination Board)

Tests of Educational Ability (T. G. Thurstone; Science Research Associates)

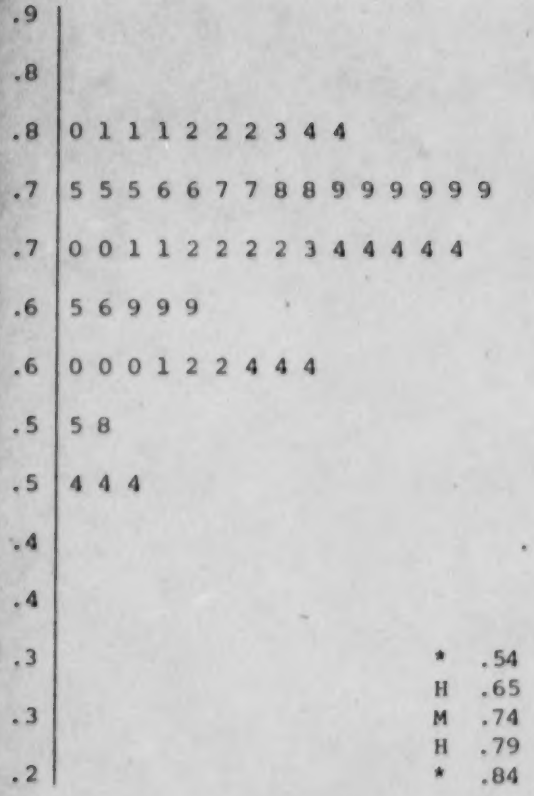
Thurstone Test of Mental Alertness (T. G. Thurstone and L. L. Thurstone, Science Research Associates)

[1]An entry of "anon." indicates the test was jointly authored by the staff of the test development organization and authorship cannot be assigned to specific individuals.

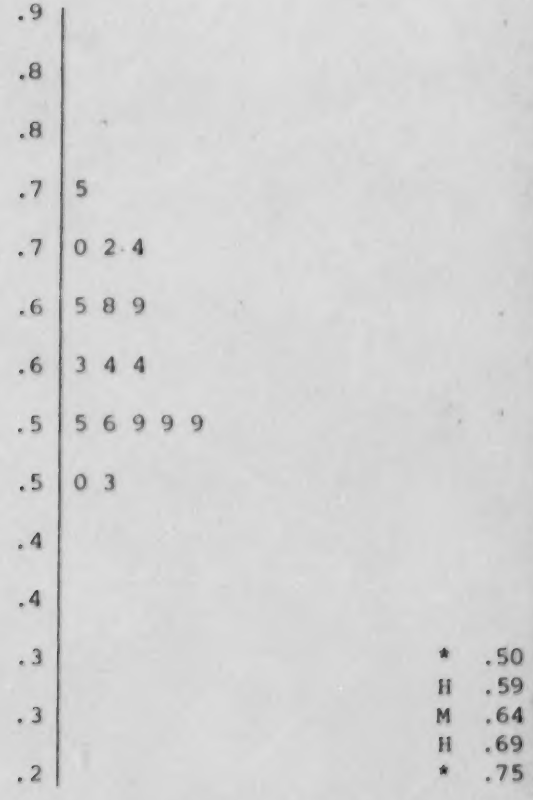
Table 4

Means, Ns, and Standard Deviations of Ability--Achievement Correlations, by Type of Ability, Type of Achievement and Grade Level

		Total Ability			Verbal Ability			Quantitative Ability			Nonverbal Ability		
Grade Range		r with Ach.tests	r with GPA	Overall	r with Ach.tests	r with GPA	Overall	r with Ach.tests	r with GPA	Overall	r with Ach.tests	r with GPA	Overall
1-4	N	21	1	22	32	0	32	2	0	2	25	1	26
	$\bar{X}$	.683	.690	.684	.714	---	.714	.570	---	.570	.604	.610	.604
	S	.090	---	.088	.080	---	.080	.028	---	.028	.065	---	.064
5-8	N	26	6	32	69	12	81	10	4	14	56	8	64
	$\bar{X}$	.735	.685	.725	.754	.629	.735	.673	.628	.660	.672	.516	.652
	S	.082	.064	.080	.088	.087	.098	.093	.043	.083	.058	.158	.092
9-12	N	11	10	21	41	11	52	5	9	14	35	1	36
	$\bar{X}$	.745	.595	.674	.758	.495	.702	.638	.488	.541	.637	.660	.638
	S	.059	.062	.096	.088	.060	.136	.175	.072	.135	.067	---	.067
Overall	N	58	17	75	142	23	165	17	13	30	116	10	126
	$\bar{X}$	.718	.633	.699	.746	.565	.721	.651	.531	.599	.647	.540	.638
	S	.084	.074	.089	.087	.101	.109	.117	.092	.121	.068	.149	.082

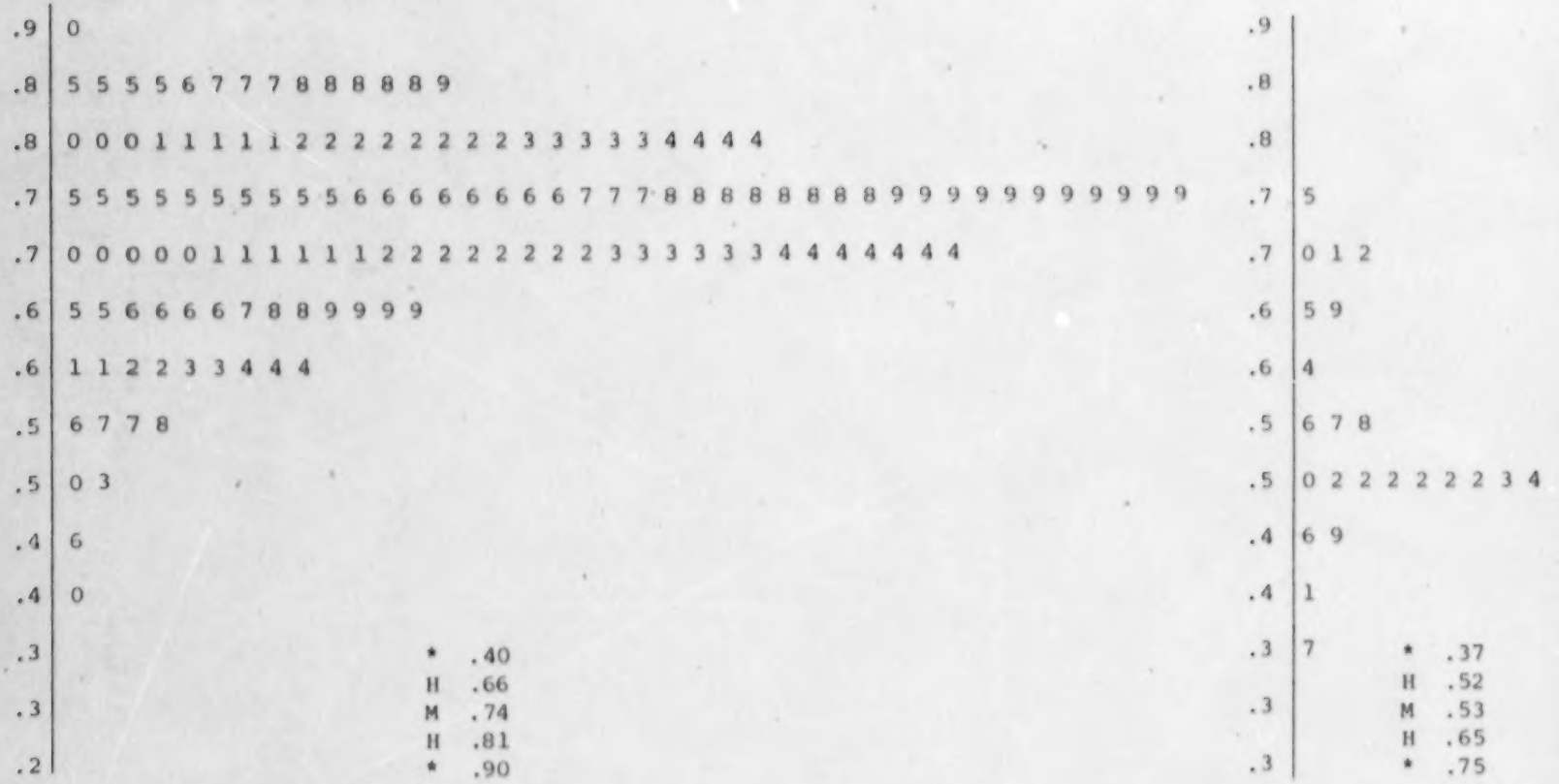


Correlations with achievement test scores
(N=58)



Correlations with grades
(N=17)

Figure 1. Stem and leaf diagrams and five-point summaries of correlations between measures of total ability and achievement (test scores and grades).



Correlations with achievement test scores (N=142)

Correlations with grades (N=23)

Figure 2. Stem and leaf diagrams and fine-point summaries of correlation between measures of verbal ability and achievement (test scores and grades).

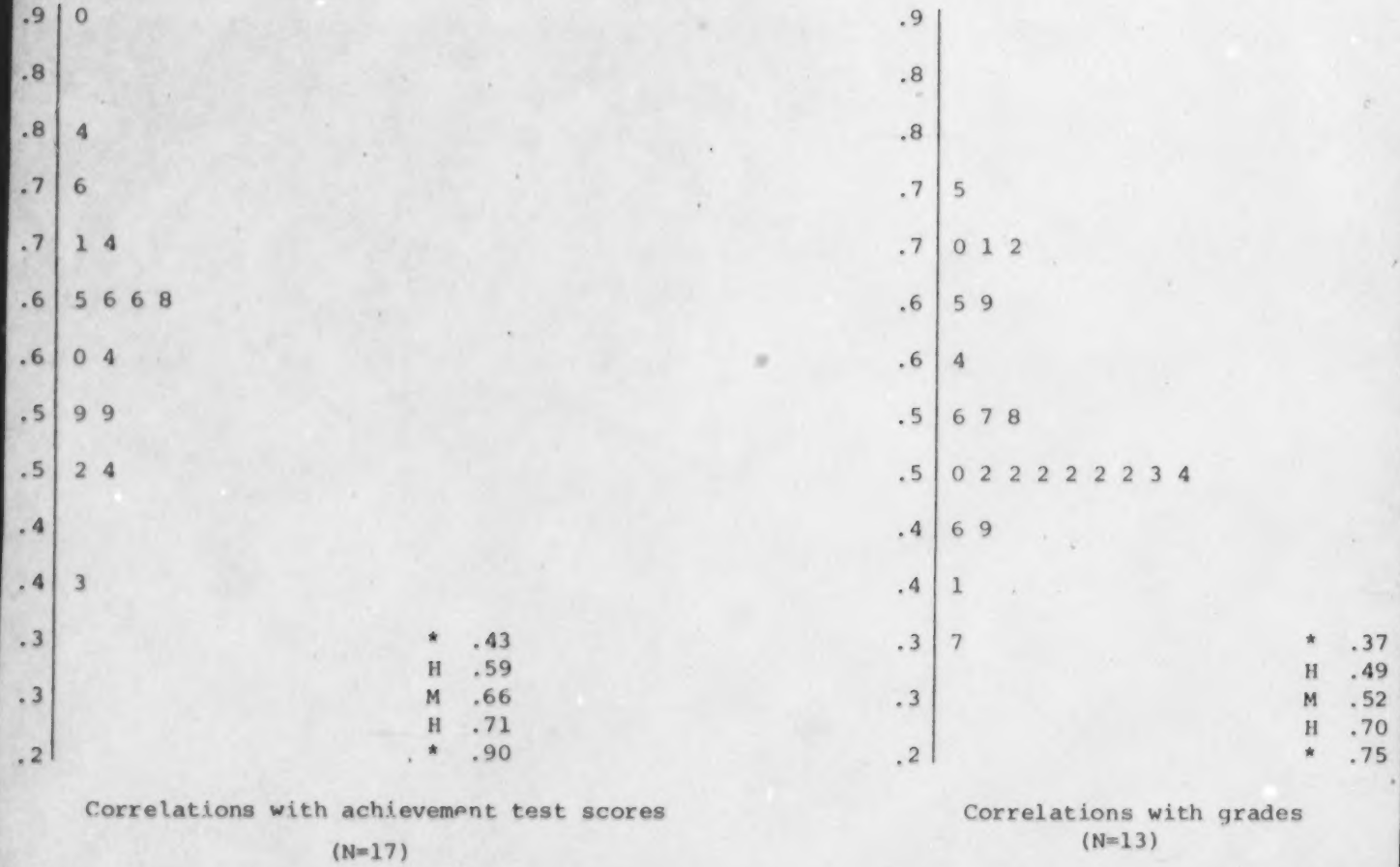


Figure 3. Stem and leaf diagrams and five-point summaries of correlations between measures of quantitative ability and achievement (test scores and grades).

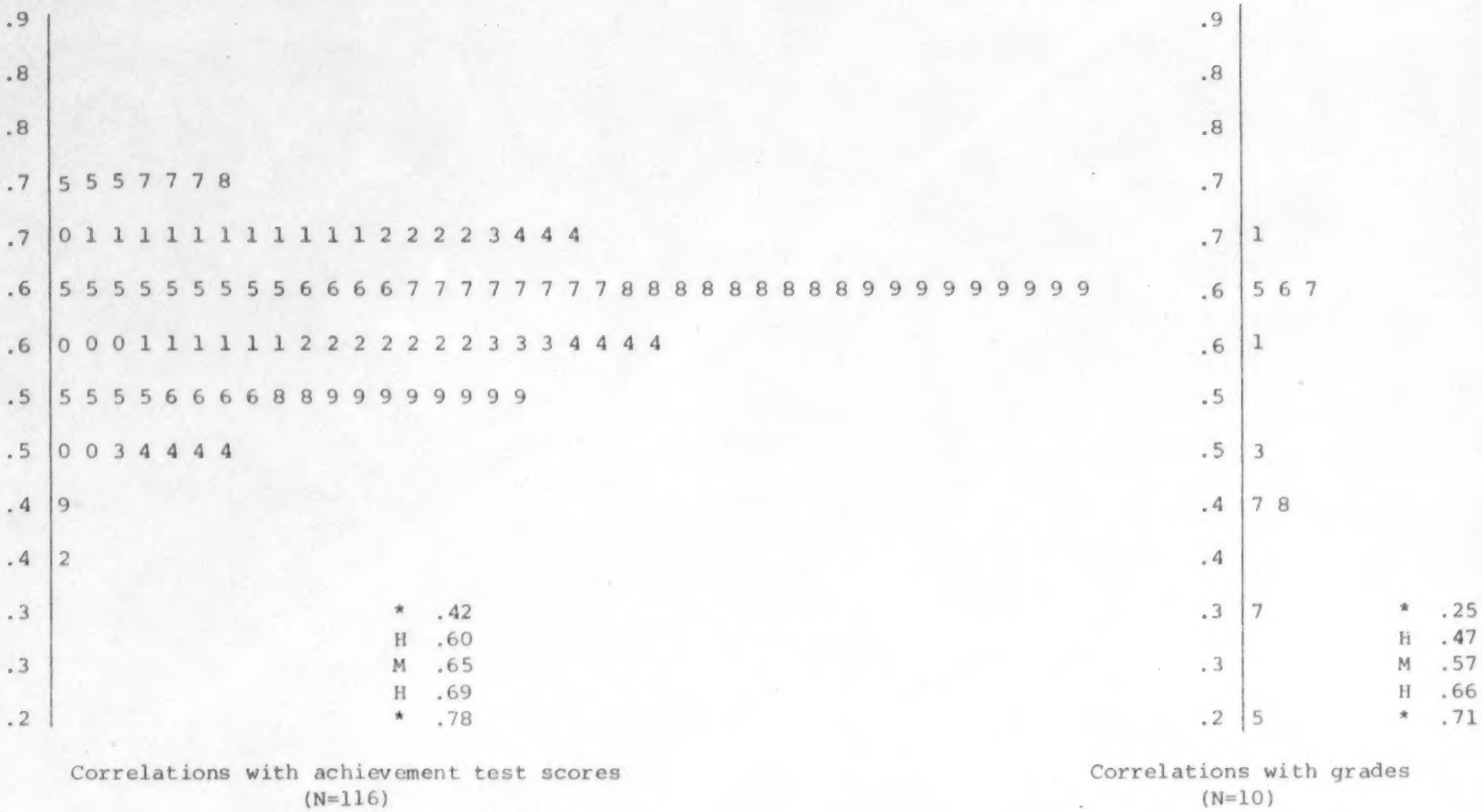


Figure 4. Stem and leaf diagrams and five-point summaries of correlations between measures of non-verbal ability and achievement (test scores and grades).